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A USER'S MANUAL FOR THE LOADED MICROSTRIP ANTENNA CODE (LMAC)

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Contents

1	Introduction	1
2	Description	2
2.1	The Loaded Microstrip Antenna	2
2.2	The Current Modes	4
2.3	Wide Band Calculations	6
3	Inputs and Outputs	7
3.1	READ Input Statements	7
3.1.1	READ #1: Program Control Parameters	7
3.1.2	READ #2: Patch Geometry and Substrate Parameters	9
3.1.3	READ #3: Incident and Radiated Angles	10
3.1.4	READ #4: Port Specifications	10
3.1.5	READ #5: Impedance Matrix Integration Parameters	11
3.1.6	READ #6: Wire Voltage Vector Integration Parameters	12
3.1.7	READ #7: Patch Mode Parameters	12
3.1.8	READ #8: Frequency Parameters	13
3.1.9	Choosing the Patch Current Modes for a Desired Frequency Band	14
3.2	Examples	14
A	Unloaded RCS Output	19
B	Loaded RCS Output	23
C	Unloaded Input Impedance and Gain Output	27

D Loaded Input Impedance and Gain Output	31
Bibliography	35

List of Figures

2.1	The geometry of the coaxially loaded microstrip antenna. .	3
2.2	Side view of a loaded microstrip antenna excited by an incident plane wave.	4
2.3	Top view of a loaded microstrip antenna excited by a wire of uniform current.	5
3.1	An abbreviated program listing showing the READ statements with line numbers.	8
3.2	The top view of the example antenna showing the location of the feed and load ports.	15
3.3	The input file used for calculating the backscatter RCS of the example microstrip antenna.	16
3.4	The input file used for calculating the loaded backscatter RCS of the example microstrip antenna.	17
3.5	The input file used for calculating the backscatter RCS of the example microstrip antenna.	17
3.6	The input file used for calculating the backscatter RCS of the example microstrip antenna.	18

Chapter 1

Introduction

This is the user's manual for the Loaded Microstrip Antenna Code. This code is named MSTRP.TP.FOR and currently resides in the directory USER2:[MICRO] on the ESL VAX 8550. The program was written, based on the Moment Method (MM), to solve for radiation and scattering from this antenna. The rectangular microstrip antenna is fed or loaded by coaxial ports. The coaxial ports are modeled as vertical wires of uniform current through the dielectric substrate. A load is modeled by a lumped impedance in the wire. The antenna can have only one feed port and one load port. When a scattering solution is desired, the far zone RCS and phase is output for both polarizations and cross polarizations. For a radiation problem, the input impedance and far zone gain for both polarizations is output.

This program was written in standard FORTRAN 77. One exception is the function GETCP(I), which returns the clock time I in hundreths of a second. This function is called to determine the total CPU time for a run.

Chapter 2 describes the geometry of the loaded microstrip antenna, defines the current modes on the patch and explains wide band calculations. Chapter 3 explains the inputs and the output for the program and gives examples.

Chapter 2

Description

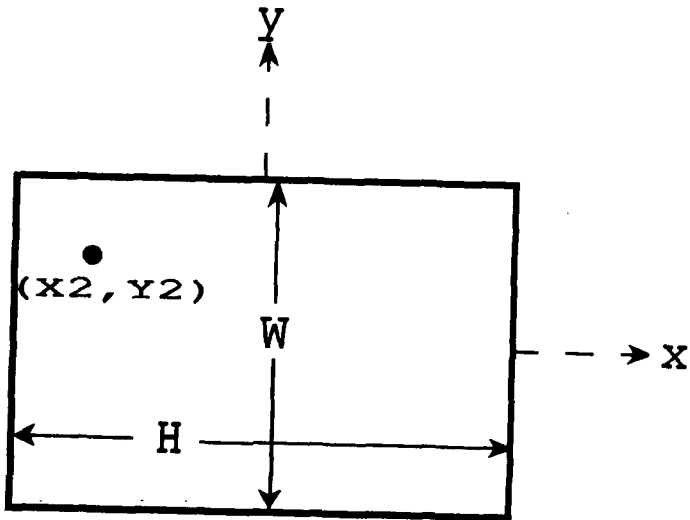
This chapter will describe the geometry of the loaded rectangular microstrip antenna, the current modes used in the MM solution, and making wideband calculations.

2.1 The Loaded Microstrip Antenna

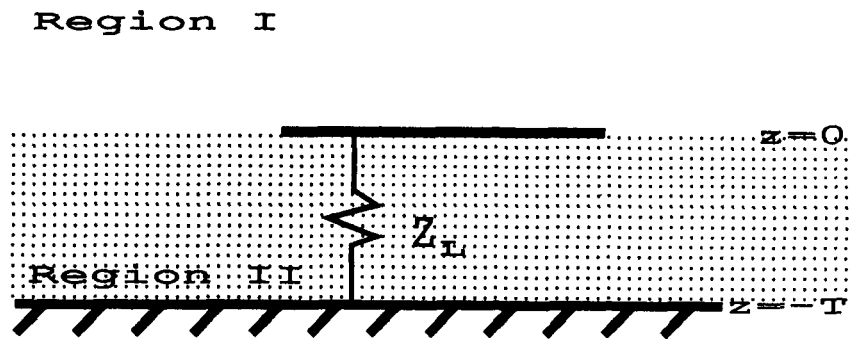
Figure 2.1 shows the geometry of the loaded microstrip antenna. It consists of a perfectly conducting rectangular patch located on top of an infinite dielectric slab of thickness T with an infinite ground plane on the other side of the dielectric slab. The structure of an infinite dielectric slab of finite thickness on top of an infinite ground plane is referred to as a grounded dielectric substrate. The coordinate system has the x axis parallel to two sides of the perfectly conducting rectangular patch and the y axis parallel to the other two sides of the patch with the origin located at the geometric center of the patch. The x directed length of the patch is H and the y directed length of the patch is W . The medium above the patch is free space. The relative permittivity of the substrate is ϵ_r , the loss tangent is $\tan \delta$, and the relative permeability of the substrate is 1.0.

The patch is loaded through a perfectly conducting wire extending vertically from the ground plane to the patch. The load exists between the wire and the ground plane and has impedance $R_L + jX_L$. The load wire is located at coordinates $(x, y) = (X_2, Y_2)$ and has a radius of A_2 . This is a model for a coaxially loaded microstrip antenna.

The loaded microstrip antenna can be excited by either an incident



a) Top view of the loaded microstrip antenna.



b) Side view of the loaded microstrip antenna.

Figure 2.1: The geometry of the coaxially loaded microstrip antenna.

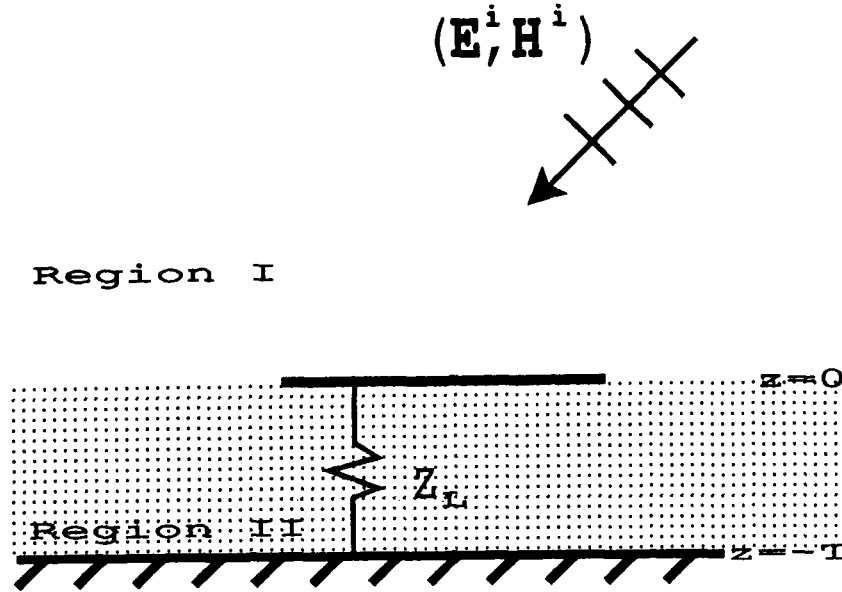


Figure 2.2: Side view of a loaded microstrip antenna excited by an incident plane wave.

plane wave or a perfectly conducting vertical wire of uniform current extending from the ground plane to the patch. Figure 2.2 shows an incident plane wave on the loaded microstrip patch antenna. The angle of incidence is $(\theta, \phi) = (\text{THETA}, \text{PHI})$ as shown. Figure 2.3 shows a loaded microstrip antenna excited by a uniform vertical current. This is a model for a coaxial feed. The wire is located at $(x, y) = (X1, Y1)$ with a radius of $A1$.

2.2 The Current Modes

A function on the patch which represents a \hat{x} directed current mode can be described by Equation 2.1.

$$J_{MN} = \sin \frac{MX\pi}{H2} \left(x + \frac{H2}{2}\right) \cos \frac{NX\pi}{W2} \left(y + \frac{W2}{2}\right) \quad (2.1)$$

The mode is described by the integer doublet (MX, NX) . MX can be any positive integer greater than zero (if $MX = 0$, $J_{MN} = 0$) and NX can be

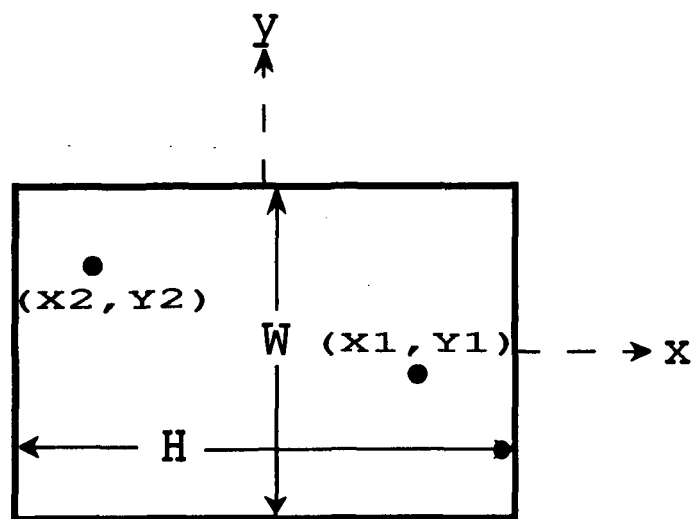


Figure 2.3: Top view of a loaded microstrip antenna excited by a wire of uniform current.

any positive integer greater than or equal to zero. A \hat{y} directed current mode can be described by

$$J_{MN} = \sin \frac{MY\pi}{W2} \left(y + \frac{W2}{2}\right) \cos \frac{NY\pi}{H2} \left(x + \frac{H2}{2}\right) \quad (2.2)$$

where MY has the same bounds as MX and NY has the same bounds as NX .

2.3 Wide Band Calculations

In order to generate wide band data without using excessive computer time, impedance matrix and wire voltage vector elements are calculated at frequency intervals defined by FSTPC and are interpolated [4] at intervals defined by FSTPI, where the MM matrix equation is solved. The impedance matrix and voltage vector elements are smoothly varying with frequency so the ratio of FSTPI to FSTPC can be very high. Refer to [2,3] for examples on values for FSTPC and FSTPI.

Chapter 3

Inputs and Outputs

The inputs and outputs for the loaded microstrip antenna code will be explained in this chapter.

3.1 READ Input Statements

A description of all the READ input statements will follow. The statements will be numbered according to the order in which they appear in the program listing. All READ input statements use a free format on logical unit 5. Figure 3.1 shows a list of the read statements as they appear in the program source code.

3.1.1 READ #1: Program Control Parameters

The first READ input statement defines the following control parameters for the program:

IPRB = type of problem to be solved.

= 0 indicates a plane wave scattering calculation is desired.

= 1 indicates an input impedance calculation is desired.

IWRZ = save impedance matrix data flag

= 0 indicates not to save the impedance matrix data.

= 1 indicates to save the impedance matrix data in logical unit 8.

Note that the impedance matrix data is only saved when the impedance matrix is calculated.

Line #	Source code
*	
*	
*	
0046	READ (5,*) IPRB,IWRZ,IRDZ,IWRV,IRDV,IPRTZ,IPRTV
*	
0055	READ (5,*) H2,W2,ER,TD,T
*	
0065	READ (5,*) TH_I,PH_I,TH_R,PH_R
*	
0084	READ (5,*) X1,Y1,A1,X2,Y2,A2,RL,XL,INDL
*	
0095	READ (5,*) DALOP,NSKP,DKIOP,RKP,EPSP
*	
0106	READ (5,*) DALOW,NSKW,DKIOW,RKW,EPSP
*	
0117	READ (5,*) INMD,MXMAX,NXMAX,MYMAX,NYMAX
*	
0127	READ (5,*) IFRQ,FSTRT,FSTOP,FSTPC,FSTPI
*	
*	
*	

Figure 3.1: An abbreviated program listing showing the READ statements with line numbers.

IRDZ = read impedance matrix data flag
 = 0 indicates to calculate the impedance matrix data.
 = 1 indicates to read the impedance matrix data from logical unit 8.

IWRV = save voltage vector data flag
 = 0 indicates not to save the voltage vector data.
 = 1 indicates to save the voltage vector data in logical unit 4. Note that the voltage vector data is only saved when the voltage vector is calculated.

IRDV = read voltage vector data flag
 = 0 indicates to calculate the voltage vector data.
 = 1 indicates to read the voltage vector data from logical unit 4.

IPRTZ = print the impedance matrix elements at each data point in the output file (logical unit 6).
 = 0 indicates not to print it.
 = 1 indicates to print it.

IPRTV = print the voltage vector elements and current column vector elements at each data point in the output file (logical unit 6).
 = 0 indicates not to print it.
 = 1 indicates to print it. This will also print the modal voltages at Port 2.

3.1.2 READ #2: Patch Geometry and Substrate Parameters

This READ input statement defines the following microstrip patch dimensions and grounded dielectric substrate parameters:

H = the x directed length of the microstrip patch in meters.

W = the y directed length of the microstrip patch in meters.

ER = the relative permittivity of the dielectric.

TD = the loss tangent of the dielectric.

T = the thickness of the dielectric substrate in meters.

3.1.3 READ #3: Incident and Radiated Angles

The third READ input statement defines the following angles for the incident plane wave and the radiated field:

TH_I = the theta angle of the incident plane wave.

PH_I = the phi angle of the incident plane wave.

TH_R = the theta angle of the radiated or scattered field.

PH_R = the phi angle of the radiated or scattered field.

3.1.4 READ #4: Port Specifications

The fourth READ input statement defines the following parameters used to define the locations of the coaxial ports and the load impedance.

X1 = the x location of the feed wire in meters.

Y1 = the y location of the feed wire in meters.

A1 = the radius of the feed wire in meters.

If $A1 \leq 0$, the feed wire is modeled as a filament at (X1,Y1).

X2 = the x location of the load wire in meters.

Y2 = the y location of the load wire in meters.

A2 = the radius of the load wire in meters.

If $A2 \leq 0$, the load wire is modeled as a filament at (X2,Y2).

RL = the resistance of the load in ohms.

If $RL < 0$, the load is an open circuit.

XL = the reactance of the load in ohms.

INDL = the reactance type indicator.

= 0 indicates that the reactance is fixed with the value XL over the entire frequency band.

= 1 indicates the reactance behaves as an inductor with XL being the

reactance of that inductor at FSTRT.
= 2 indicates the reactance behaves as a capacitor with XL being the reactance of that capacitor at FSTRT.

3.1.5 READ #5: Impedance Matrix Integration Parameters

The fifth READ input statement defines the following integration parameters used to compute the impedance matrix elements:

DALPP = the Simpson's rule integration interval for the α integral in degrees.

When DALPP is divided into 90, the result should be an even number. Typically 3.0 is chosen.

NSKP = the number of Simpson's rule integration intervals per κ_0 for the κ integral.

NSKP is always even and is typically chosen as 6.

DKIOP = the integration path stagger in κ_0 .

This is the stagger used to avoid singularities along the $\text{Re}(\kappa)$ axis and is typically chosen as 0.1 .

RKMP = the upper limit of integration in κ_0 .

The endpoints of the κ integral are 0 and ∞ . Since the infinite bound is impractical, a finite value is chosen. Typically this is 50.0 .

EPSP = the convergence test limit for the κ integral.

When the contribution from a Simpson's integration point divided by the value of the integral at that point is less than EPSP, the integral is considered adequately converged and the integration is terminated. When $\text{EPSP} < 0$, the integral is evaluated to RKMP. If $\text{EPSP} > 0.0$ and the integration does not terminate before RKMP is reached, an error message is printed in the output. The impedance matrix of the microstrip patch is symmetric, best results for a symmetric matrix are obtained when $\text{EPSP} < 0.0$.

3.1.6 READ #6: Wire Voltage Vector Integration Parameters

The sixth READ input statement defines the following integration parameters used to compute the voltage vector elements of a wire:

DALPW = the Simpson's rule integration interval for the α integral in degrees.

When DALPW is divided into 90, the result should be an even number. Typically 3.0 is chosen.

NSKW = the number of Simpson's rule integration intervals per κ_0 for the κ integral.

NSKW is always even and is typically chosen as 6.

DKIOW = the integration path stagger in κ_0 .

This is the stagger used to avoid singularities along the $\text{Re}(\kappa)$ axis and is typically chosen as 0.1 .

RKMW = the upper limit of integration in κ_0 .

The endpoints of the κ integral are 0 and ∞ . Since the infinite bound is impractical, a finite value is chosen. Typically this is 300.0.

EPSW = the convergence test limit for the κ integral.

When the contribution from a Simpson's integration point divided by the value of the integral at that point is less than EPSW, the integral is considered adequately converged and the integration is terminated. When $\text{EPSW} < 0$, the integral is evaluated to RKMW. If $\text{EPSW} > 0.0$ and the integration does not terminate before RKMW is reached, an error message is printed in the output. A typical value for EPSW is 0.001 .

3.1.7 READ #7: Patch Mode Parameters

The seventh READ input statement defines the following parameters used to describe the current modes on the microstrip patch:

INMD = indicates whether MXMAX, NXMAX, MYMAX, and NYMAX describe single modes or multiple modes.

= 0 indicates that only one x polarized and one y polarized mode is used in the computation. The x polarized mode is defined by MXMAX and NXMAX, the y polarized mode is defined by MYMAX and NYMAX.

= 1 indicates that all x polarized modes up to and including the mode defined by MXMAX and NXMAX and that all y polarized modes up to and including the mode defined by MYMAX and NYMAX are used in the computation. INMD = 1 is normally desired for all computations.

= 2 indicates that MXMAX, NXMAX, MYMAX, and NYMAX are automatically computed by the algorithm stated in Subsection 3.1.9.

MXMAX = the first number of a doublet which describes a single or maximum x polarized mode.

If x polarized modes are desired, MXMAX must be ≥ 1 .

NXMAX = the second number of a doublet that describes a single or maximum x polarized mode.

NXMAX must be ≥ 0 .

MYMAX = the first number of a doublet which describes a single or maximum y polarized mode.

If y polarized modes are desired, MYMAX must be ≥ 1 .

NYMAX = the second number of a doublet that describes a single or maximum y polarized mode.

NYMAX must be ≥ 0 .

3.1.8 READ #8: Frequency Parameters

The eighth and final READ input statement describes the following frequency parameters:

IFRQ = indicator for single frequency or wide band calculation.

= 0 indicates that a wide band calculation is desired between the band defined by FSTRT and FSTOP.

= 1 indicates that a calculation at the frequency chosen by FSTRT is desired.

FSTRT = the start frequency of a wideband calculation or the frequency of a single frequency calculation in MHz.

FSTOP = the stop frequency of a wide band frequency calculation in MHz.

FSTPC = the step size in MHz for calculating the impedance matrix and voltage vector elements.

FSTPI = the step size in MHz for the MM solution.

3.1.9 Choosing the Patch Current Modes for a Desired Frequency Band

When modes that resonate above the desired frequency band are included in a loaded microstrip antenna calculation, large errors can occur compared to measurement. It is believed that these errors are due to the lack of an attachment mode between the vertical wire and the patch. By breaking up the desired frequency band into regions that span up to two octaves maximum, reasonable results are usually obtained using the following algorithm:

$$\begin{aligned} MXMAX &= \frac{2 \times H^2}{\lambda_{max}} \\ &= NYMAX \end{aligned} \quad (3.1)$$

$$\begin{aligned} MYMAX &= \frac{2 \times W^2}{\lambda_{max}} \\ &= NXMAX \end{aligned} \quad (3.2)$$

where

$$\lambda_{max} = \frac{300}{\sqrt{ER} \times FSTOP} \quad (3.3)$$

This algorithm is built into the program and used when INMD = 2.

3.2 Examples

In this section 4 examples will be presented to demonstrate the use of this computer program in determining plane wave scattering and input impedance of a loaded microstrip antenna. These examples will show the

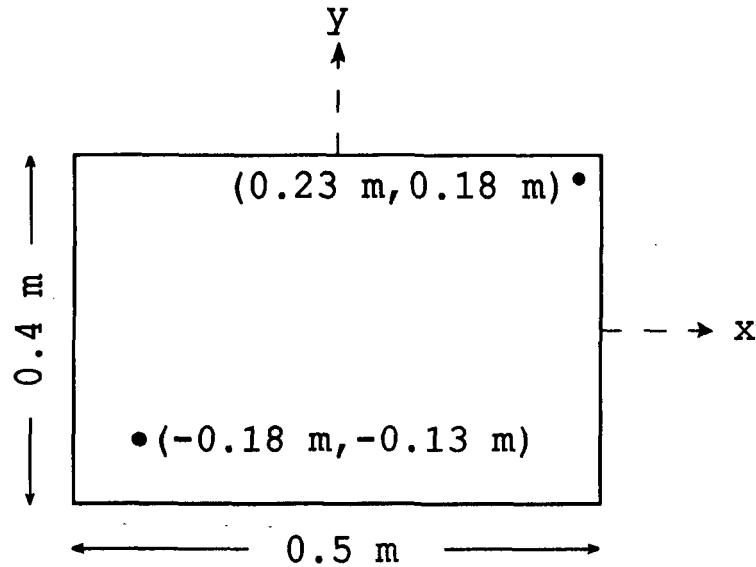


Figure 3.2: The top view of the example antenna showing the location of the feed and load ports.

inputs required and outputs obtained for the defined geometries. The top view of this antenna is shown in Figure 3.2. It is seen from this Figure that the patch is 0.5 m in the \hat{x} direction and 0.4 m in the \hat{y} direction. The current filament for excitation is located at $(x_f, y_f) = (0.23 \text{ m}, 0.18 \text{ m})$. The current filament for loading is located at $(x_L, y_L) = (0.18 \text{ cm}, 0.13 \text{ cm})$. The antenna will be loaded by 25 ohms. The thickness of the dielectric is 0.02 m with a dielectric constant of 2.5 and a loss tangent of 0.001.

The first example is the radar cross section (RCS) of the unloaded antenna. The impedance matrix elements for this antenna are computed. The number of modes is chosen by the internal algorithm. The start frequency is 150 MHz and the stop frequency is 350 MHz. The impedance matrix and voltage vector elements are computed every 100 MHz and data is output every 2 MHz. The integration parameters are the default parameters listed in the READ statement descriptions. Figure 3.3 shows the input file for this calculation. The output is shown in Appendix A.

The second example is the loaded backscatter RCS of the antenna. Fig-

Description	Input file
READ #1:	0 1 0 1 0 0 0
READ #2:	0.5 0.4 2.5 0.001 0.02
READ #3:	60.0 45.0 60.0 45.0
READ #4:	0.23 0.18 0.0 -0.18 -0.13 0.0 -25.0 0.0 0
READ #5:	3.0 6 0.1 50.0 -1.0
READ #6:	3.0 6 0.1 300.0 0.001
READ #7:	2 1 0 0 0
READ #8:	0 150.0 350.0 100.0 2.0

Figure 3.3: The input file used for calculating the backscatter RCS of the example microstrip antenna.

ure 3.4 shows the input file to calculate the loaded RCS. Notice that the only changes made were reading the impedance matrix data instead of calculating it and the load resistance was made positive to signal that the loaded calculation was desired. Appendix B shows the output of this run.

The third example is the unloaded input impedance of the antenna. Figure 3.5 shows the input file to calculate the unloaded input impedance. Again, since the frequency band and impedance matrix integration parameters remain the same, the impedance matrix data is read rather than calculated. The load resistance is negative to indicate an unloaded calculation is desired. IPRB is changed to 1 to indicate that input impedance is to be calculated. Appendix C shows the output of the computer program for this input file.

The final example is the loaded input impedance of the antenna. Figure 3.6 shows the input file to calculate the loaded input impedance. The only difference between this input file and the unloaded input impedance input file is the sign on the input resistance. Appendix D shows the output of the computer program for this input file.

Description	Input file
READ #1:	0 0 1 1 0 0 0
READ #2:	0.5 0.4 2.5 0.001 0.02
READ #3:	60.0 45.0 60.0 45.0
READ #4:	0.23 0.18 0.0 -0.18 -0.13 0.0 25.0 0.0 0
READ #5:	3.0 6 0.1 50.0 -1.0
READ #6:	3.0 6 0.1 300.0 0.001
READ #7:	2 1 0 0 0
READ #8:	0 150.0 350.0 100.0 2.0

Figure 3.4: The input file used for calculating the loaded backscatter RCS of the example microstrip antenna.

Description	Input file
READ #1:	1 0 1 1 0 0 0
READ #2:	0.5 0.4 2.5 0.001 0.02
READ #3:	60.0 45.0 60.0 45.0
READ #4:	0.23 0.18 0.0 -0.18 -0.13 0.0 -25.0 0.0 0
READ #5:	3.0 6 0.1 50.0 -1.0
READ #6:	3.0 6 0.1 300.0 0.001
READ #7:	2 1 0 0 0
READ #8:	0 150.0 350.0 100.0 2.0

Figure 3.5: The input file used for calculating the backscatter RCS of the example microstrip antenna.

Description	Input file
READ #1:	1 0 1 1 0 0 0
READ #2:	0.5 0.4 2.5 0.001 0.02
READ #3:	60.0 45.0 60.0 45.0
READ #4:	0.23 0.18 0.0 -0.18 -0.13 0.0 25.0 0.0 0
READ #5:	3.0 6 0.1 50.0 -1.0
READ #6:	3.0 6 0.1 300.0 0.001
READ #7:	2 1 0 0 0
READ #8:	0 150.0 350.0 100.0 2.0

Figure 3.6: The input file used for calculating the backscatter RCS of the example microstrip antenna.

Appendix A

Unloaded RCS Output

Solution for radar cross section (RCS) of a microstrip patch centered at the origin.

X directed length of the patch = 50.000 cm

Y directed width of the patch = 40.000 cm

Thickness of the substrate = 2.0000 cm

Dielectric constant = 2.50 Loss tangent = 0.0010

Incident angle of plane wave: Theta = 60.00 deg., Phi = 45.00 deg.

Location of load port: X = -18.000 cm, Y = -13.000 cm

with wire radius = 0.0000 cm

Angle of scattered field: Theta = 60.00 deg., Phi = 45.00 deg.

Load port is open circuited.

Mode information:

Number of modes = 4

Modes:

1 0 X polarized

1 1 X polarized

1 0 Y polarized

1 1 Y polarized

FMHZ	***** RCS IN DB *****				**** PHASE IN DEGREES ****			
	TH-TH	TH-PH	PH-TH	PH-PH	TH-TH	TH-PH	PH-TH	PH-PH
150.0	-32.66	-42.57	-42.57	-37.84	-10.9	171.8	171.8	-4.4
152.0	-31.92	-41.61	-41.61	-37.11	-11.1	171.6	171.6	-4.5
154.0	-31.16	-40.62	-40.62	-36.37	-11.3	171.4	171.4	-4.6
156.0	-30.38	-39.60	-39.60	-35.61	-11.6	171.2	171.2	-4.7
158.0	-29.58	-38.55	-38.55	-34.82	-11.8	171.0	171.0	-4.9

160.0	-28.75	-37.45	-37.45	-34.01	-12.1	170.7	170.7	-5.1
162.0	-27.88	-36.31	-36.31	-33.16	-12.3	170.4	170.4	-5.2
164.0	-26.97	-35.11	-35.11	-32.27	-12.6	170.1	170.1	-5.5
166.0	-26.02	-33.85	-33.85	-31.34	-13.0	169.7	169.7	-5.7
168.0	-25.00	-32.52	-32.52	-30.35	-13.4	169.3	169.3	-6.0
170.0	-23.92	-31.10	-31.10	-29.29	-13.8	168.8	168.8	-6.4
172.0	-22.74	-29.57	-29.57	-28.14	-14.4	168.2	168.2	-6.8
174.0	-21.45	-27.89	-27.89	-26.88	-15.1	167.4	167.4	-7.4
176.0	-20.00	-26.04	-26.04	-25.47	-16.0	166.4	166.4	-8.2
178.0	-18.33	-23.95	-23.95	-23.84	-17.2	165.1	165.1	-9.3
180.0	-16.36	-21.52	-21.52	-21.91	-19.0	163.2	163.2	-11.0
182.0	-13.91	-18.58	-18.58	-19.50	-21.8	160.2	160.2	-13.8
184.0	-10.64	-14.78	-14.78	-16.28	-27.3	154.5	154.5	-19.2
186.0	-5.82	-9.38	-9.38	-11.51	-41.3	140.2	140.2	-33.0
188.0	-0.25	-3.19	-3.19	-6.00	-94.9	86.4	86.4	-86.5
190.0	-5.25	-7.50	-7.50	-11.07	-155.1	25.8	25.8	-146.5
192.0	-10.43	-11.92	-11.92	-16.33	-170.8	9.6	9.6	-162.1
194.0	-13.98	-14.61	-14.61	-19.97	-176.5	3.3	3.3	-167.6
196.0	-16.71	-16.38	-16.38	-22.81	-179.1	0.0	0.0	-170.0
198.0	-19.03	-17.59	-17.59	-25.26	179.8	-2.2	-2.2	-170.9
200.0	-21.15	-18.43	-18.43	-27.55	179.6	-3.8	-3.8	-170.7
202.0	-23.25	-18.99	-18.99	-29.88	-179.7	-5.0	-5.0	-169.4
204.0	-25.49	-19.34	-19.34	-32.44	-177.7	-6.1	-6.1	-166.4
206.0	-28.06	-19.50	-19.50	-35.51	-173.4	-7.2	-7.2	-159.8
208.0	-31.29	-19.49	-19.49	-39.42	-164.0	-8.2	-8.2	-143.8
210.0	-35.20	-19.33	-19.33	-42.64	-139.5	-9.3	-9.3	-101.4
212.0	-35.82	-19.01	-19.01	-39.50	-88.6	-10.4	-10.4	-54.6
214.0	-31.25	-18.53	-18.53	-34.85	-55.8	-11.8	-11.8	-36.3
216.0	-26.85	-17.87	-17.87	-31.03	-44.0	-13.4	-13.4	-29.5
218.0	-23.14	-16.99	-16.99	-27.75	-39.7	-15.5	-15.5	-27.1
220.0	-19.78	-15.86	-15.86	-24.68	-38.9	-18.2	-18.2	-27.1
222.0	-16.48	-14.39	-14.39	-21.61	-40.6	-22.2	-22.2	-29.2
224.0	-13.01	-12.47	-12.47	-18.33	-45.3	-28.5	-28.5	-34.1
226.0	-9.17	-9.98	-9.98	-14.64	-55.4	-39.7	-39.7	-44.3
228.0	-5.11	-7.13	-7.13	-10.72	-77.2	-62.3	-62.3	-66.1
230.0	-3.07	-6.17	-6.17	-8.81	-115.9	-101.7	-101.7	-104.8
232.0	-4.79	-8.87	-8.87	-10.65	-148.9	-135.1	-135.1	-137.7
234.0	-7.23	-12.22	-12.22	-13.21	-165.4	-152.1	-152.1	-154.2
236.0	-9.18	-15.02	-15.02	-15.29	-173.9	-160.8	-160.8	-162.6

238.0	-10.67	-17.30	-17.30	-16.90	-178.8	-166.0	-166.0	-167.4
240.0	-11.83	-19.20	-19.20	-18.18	178.1	-169.4	-169.4	-170.4
242.0	-12.74	-20.81	-20.81	-19.22	175.9	-171.7	-171.7	-172.5
244.0	-13.47	-22.20	-22.20	-20.08	174.3	-173.5	-173.5	-174.0
246.0	-14.06	-23.43	-23.43	-20.82	173.0	-174.9	-174.9	-175.1
248.0	-14.55	-24.52	-24.52	-21.45	172.0	-176.0	-176.0	-176.0
250.0	-14.95	-25.49	-25.49	-22.00	171.1	-177.0	-177.0	-176.6
252.0	-15.27	-26.36	-26.36	-22.48	170.4	-177.8	-177.8	-177.2
254.0	-15.53	-27.15	-27.15	-22.92	169.8	-178.5	-178.5	-177.7
256.0	-15.73	-27.86	-27.86	-23.30	169.2	-179.2	-179.2	-178.1
258.0	-15.87	-28.49	-28.49	-23.65	168.6	-179.8	-179.8	-178.4
260.0	-15.97	-29.05	-29.05	-23.97	168.1	179.6	179.6	-178.7
262.0	-16.02	-29.55	-29.55	-24.25	167.7	179.0	179.0	-178.9
264.0	-16.03	-29.98	-29.98	-24.52	167.2	178.4	178.4	-179.1
266.0	-15.99	-30.34	-30.34	-24.75	166.7	177.8	177.8	-179.3
268.0	-15.89	-30.63	-30.63	-24.97	166.2	177.2	177.2	-179.5
270.0	-15.75	-30.85	-30.85	-25.17	165.7	176.5	176.5	-179.7
272.0	-15.55	-30.99	-30.99	-25.35	165.2	175.8	175.8	-179.8
274.0	-15.29	-31.04	-31.04	-25.52	164.6	175.0	175.0	-179.9
276.0	-14.96	-30.99	-30.99	-25.66	164.0	174.1	174.1	179.9
278.0	-14.54	-30.83	-30.83	-25.79	163.3	173.1	173.1	179.8
280.0	-14.02	-30.53	-30.53	-25.90	162.5	172.0	172.0	179.6
282.0	-13.38	-30.08	-30.08	-25.99	161.5	170.7	170.7	179.4
284.0	-12.58	-29.43	-29.43	-26.04	160.3	169.1	169.1	179.2
286.0	-11.58	-28.53	-28.53	-26.06	158.7	167.0	167.0	178.9
288.0	-10.28	-27.30	-27.30	-26.03	156.5	164.4	164.4	178.5
290.0	-8.55	-25.59	-25.59	-25.91	153.1	160.5	160.5	177.7
292.0	-6.15	-23.15	-23.15	-25.62	147.2	154.1	154.1	175.9
294.0	-2.59	-19.51	-19.51	-25.07	134.3	140.6	140.6	171.0
296.0	1.84	-14.93	-14.93	-25.04	96.0	101.9	101.9	153.1
298.0	-0.55	-17.12	-17.12	-30.11	35.1	40.4	40.4	150.5
300.0	-5.92	-22.23	-22.23	-30.30	11.2	16.0	16.0	171.0
302.0	-9.93	-25.91	-25.91	-29.61	2.1	6.4	6.4	176.4
304.0	-13.01	-28.61	-28.61	-29.25	-2.6	1.3	1.3	178.1
306.0	-15.54	-30.70	-30.70	-29.07	-5.5	-2.1	-2.1	178.8
308.0	-17.72	-32.38	-32.38	-28.99	-7.6	-4.5	-4.5	179.2
310.0	-19.65	-33.75	-33.75	-28.95	-9.3	-6.4	-6.4	179.4
312.0	-21.41	-34.89	-34.89	-28.94	-10.7	-8.0	-8.0	179.6
314.0	-23.05	-35.86	-35.86	-28.96	-11.9	-9.3	-9.3	179.6

316.0	-24.58	-36.67	-36.67	-28.99	-13.1	-10.4	-10.4	179.7
318.0	-26.04	-37.35	-37.35	-29.03	-14.2	-11.3	-11.3	179.8
320.0	-27.43	-37.93	-37.93	-29.07	-15.4	-12.1	-12.1	179.8
322.0	-28.78	-38.42	-38.42	-29.12	-16.6	-12.8	-12.8	179.9
324.0	-30.09	-38.83	-38.83	-29.17	-17.9	-13.4	-13.4	179.9
326.0	-31.36	-39.18	-39.18	-29.23	-19.2	-14.0	-14.0	180.0
328.0	-32.61	-39.47	-39.47	-29.29	-20.7	-14.4	-14.4	-180.0
330.0	-33.83	-39.70	-39.70	-29.35	-22.4	-14.8	-14.8	-179.9
332.0	-35.02	-39.90	-39.90	-29.41	-24.3	-15.1	-15.1	-179.9
334.0	-36.19	-40.05	-40.05	-29.47	-26.4	-15.4	-15.4	-179.8
336.0	-37.32	-40.17	-40.17	-29.53	-28.7	-15.7	-15.7	-179.7
338.0	-38.41	-40.26	-40.26	-29.60	-31.3	-15.9	-15.9	-179.7
340.0	-39.46	-40.33	-40.33	-29.66	-34.2	-16.1	-16.1	-179.6
342.0	-40.44	-40.37	-40.37	-29.73	-37.4	-16.2	-16.2	-179.6
344.0	-41.35	-40.39	-40.39	-29.80	-40.8	-16.3	-16.3	-179.5
346.0	-42.17	-40.39	-40.39	-29.86	-44.4	-16.5	-16.5	-179.4
348.0	-42.88	-40.38	-40.38	-29.93	-48.1	-16.5	-16.5	-179.3
350.0	-43.48	-40.36	-40.36	-30.00	-51.8	-16.6	-16.6	-179.3

CPU time = 00:00:45

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Appendix B

Loaded RCS Output

Solution for radar cross section (RCS) of a microstrip patch
centered at the origin.

X directed length of the patch = 50.000 cm

Y directed width of the patch = 40.000 cm

Thickness of the substrate = 2.0000 cm

Dielectric constant = 2.50 Loss tangent = 0.0010

Incident angle of plane wave: Theta = 60.00 deg., Phi = 45.00 deg.

Location of load port: X = -18.000 cm, Y = -13.000 cm

with wire radius = 0.0000 cm

Angle of scattered field: Theta = 60.00 deg., Phi = 45.00 deg.

Load port is terminated by 25.0 +j 0.0 ohms.

Mode information:

Number of modes = 4

Modes:

1 0 X polarized

1 1 X polarized

1 0 Y polarized

1 1 Y polarized

FMHZ	***** RCS IN DB *****				***** PHASE IN DEGREES *****			
	TH-TH	TH-PH	PH-TH	PH-PH	TH-TH	TH-PH	PH-TH	PH-PH
150.0	-39.96	-47.47	-47.47	-38.44	-35.4	150.2	150.2	-6.8
152.0	-39.37	-46.66	-46.66	-37.76	-35.9	149.6	149.6	-7.1
154.0	-38.78	-45.84	-45.84	-37.08	-36.5	149.0	149.0	-7.4
156.0	-38.19	-45.00	-45.00	-36.39	-37.2	148.3	148.3	-7.7
158.0	-37.59	-44.15	-44.15	-35.69	-37.8	147.6	147.6	-8.0

160.0	-36.99	-43.28	-43.28	-34.97	-38.6	146.8	146.8	-8.4
162.0	-36.38	-42.40	-42.40	-34.24	-39.4	146.0	146.0	-8.9
164.0	-35.76	-41.49	-41.49	-33.50	-40.2	145.1	145.1	-9.3
166.0	-35.13	-40.56	-40.56	-32.73	-41.2	144.1	144.1	-9.9
168.0	-34.49	-39.60	-39.60	-31.94	-42.2	143.1	143.1	-10.5
170.0	-33.83	-38.61	-38.61	-31.13	-43.4	141.9	141.9	-11.2
172.0	-33.17	-37.59	-37.59	-30.29	-44.7	140.5	140.5	-12.0
174.0	-32.48	-36.53	-36.53	-29.41	-46.1	139.0	139.0	-13.0
176.0	-31.78	-35.43	-35.43	-28.50	-47.7	137.4	137.4	-14.1
178.0	-31.05	-34.29	-34.29	-27.55	-49.6	135.4	135.4	-15.4
180.0	-30.30	-33.09	-33.09	-26.54	-51.7	133.2	133.2	-17.0
182.0	-29.52	-31.82	-31.82	-25.49	-54.2	130.6	130.6	-18.9
184.0	-28.70	-30.50	-30.50	-24.37	-57.2	127.5	127.5	-21.3
186.0	-27.86	-29.09	-29.09	-23.18	-60.8	123.7	123.7	-24.3
188.0	-26.99	-27.61	-27.61	-21.93	-65.2	119.1	119.1	-28.0
190.0	-26.10	-26.06	-26.06	-20.60	-70.7	113.4	113.4	-32.9
192.0	-25.22	-24.45	-24.45	-19.23	-77.7	106.0	106.0	-39.2
194.0	-24.44	-22.85	-22.85	-17.87	-86.7	96.7	96.7	-47.6
196.0	-23.87	-21.37	-21.37	-16.64	-98.1	84.8	84.8	-58.3
198.0	-23.76	-20.21	-20.21	-15.74	-111.8	70.5	70.5	-71.4
200.0	-24.32	-19.57	-19.57	-15.36	-126.7	54.7	54.7	-85.8
202.0	-25.68	-19.50	-19.50	-15.56	-140.8	39.4	39.4	-99.7
204.0	-27.77	-19.85	-19.85	-16.18	-152.3	26.0	26.0	-111.6
206.0	-30.55	-20.41	-20.41	-17.03	-160.3	15.0	15.0	-120.9
208.0	-34.14	-21.03	-21.03	-17.93	-163.3	6.2	6.2	-127.8
210.0	-39.05	-21.61	-21.61	-18.80	-156.7	-1.0	-1.0	-133.0
212.0	-44.53	-22.13	-22.13	-19.59	-116.7	-7.0	-7.0	-136.8
214.0	-41.35	-22.56	-22.56	-20.31	-62.4	-12.2	-12.2	-139.6
216.0	-36.70	-22.91	-22.91	-20.94	-48.1	-16.8	-16.8	-141.6
218.0	-33.50	-23.18	-23.18	-21.48	-45.3	-21.1	-21.1	-143.1
220.0	-31.12	-23.39	-23.39	-21.94	-46.0	-25.3	-25.3	-144.1
222.0	-29.22	-23.54	-23.54	-22.32	-48.0	-29.4	-29.4	-144.9
224.0	-27.62	-23.64	-23.64	-22.63	-50.8	-33.5	-33.5	-145.4
226.0	-26.22	-23.70	-23.70	-22.86	-54.2	-37.7	-37.7	-145.8
228.0	-24.96	-23.74	-23.74	-23.03	-58.0	-42.1	-42.1	-146.1
230.0	-23.83	-23.76	-23.76	-23.13	-62.3	-46.8	-46.8	-146.5
232.0	-22.81	-23.77	-23.77	-23.17	-67.1	-51.8	-51.8	-147.1
234.0	-21.88	-23.81	-23.81	-23.17	-72.2	-57.1	-57.1	-147.9
236.0	-21.06	-23.87	-23.87	-23.14	-77.8	-62.7	-62.7	-149.0

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238.0	-20.35	-23.99	-23.99	-23.10	-83.7	-68.6	-68.6	-150.4
240.0	-19.75	-24.17	-24.17	-23.06	-89.9	-74.7	-74.7	-152.1
242.0	-19.28	-24.44	-24.44	-23.04	-96.2	-80.9	-80.9	-154.1
244.0	-18.93	-24.79	-24.79	-23.06	-102.6	-87.1	-87.1	-156.3
246.0	-18.69	-25.22	-25.22	-23.13	-108.8	-93.1	-93.1	-158.7
248.0	-18.57	-25.73	-25.73	-23.24	-114.8	-98.9	-98.9	-161.0
250.0	-18.53	-26.31	-26.31	-23.39	-120.5	-104.3	-104.3	-163.2
252.0	-18.57	-26.95	-26.95	-23.57	-125.7	-109.2	-109.2	-165.2
254.0	-18.67	-27.62	-27.62	-23.78	-130.6	-113.7	-113.7	-167.1
256.0	-18.81	-28.31	-28.31	-24.00	-135.0	-117.7	-117.7	-168.7
258.0	-18.97	-29.02	-29.02	-24.23	-139.0	-121.2	-121.2	-170.2
260.0	-19.16	-29.73	-29.73	-24.46	-142.6	-124.4	-124.4	-171.5
262.0	-19.36	-30.43	-30.43	-24.69	-145.9	-127.1	-127.1	-172.6
264.0	-19.56	-31.13	-31.13	-24.91	-148.9	-129.6	-129.6	-173.5
266.0	-19.76	-31.81	-31.81	-25.13	-151.6	-131.7	-131.7	-174.3
268.0	-19.95	-32.48	-32.48	-25.34	-154.1	-133.6	-133.6	-175.0
270.0	-20.15	-33.14	-33.14	-25.54	-156.3	-135.2	-135.2	-175.6
272.0	-20.33	-33.77	-33.77	-25.73	-158.4	-136.7	-136.7	-176.1
274.0	-20.51	-34.39	-34.39	-25.91	-160.4	-138.0	-138.0	-176.6
276.0	-20.68	-35.00	-35.00	-26.09	-162.3	-139.2	-139.2	-177.0
278.0	-20.85	-35.59	-35.59	-26.25	-164.0	-140.2	-140.2	-177.3
280.0	-21.01	-36.17	-36.17	-26.41	-165.6	-141.2	-141.2	-177.6
282.0	-21.16	-36.75	-36.75	-26.55	-167.2	-142.1	-142.1	-177.9
284.0	-21.32	-37.31	-37.31	-26.70	-168.7	-143.0	-143.0	-178.1
286.0	-21.47	-37.88	-37.88	-26.83	-170.2	-143.8	-143.8	-178.3
288.0	-21.62	-38.44	-38.44	-26.96	-171.6	-144.6	-144.6	-178.5
290.0	-21.77	-39.01	-39.01	-27.08	-173.0	-145.4	-145.4	-178.7
292.0	-21.92	-39.59	-39.59	-27.20	-174.3	-146.1	-146.1	-178.8
294.0	-22.07	-40.18	-40.18	-27.32	-175.6	-146.7	-146.7	-179.0
296.0	-22.22	-40.78	-40.78	-27.43	-176.8	-147.3	-147.3	-179.1
298.0	-22.38	-41.40	-41.40	-27.54	-178.0	-147.9	-147.9	-179.2
300.0	-22.54	-42.04	-42.04	-27.64	-179.1	-148.4	-148.4	-179.3
302.0	-22.70	-42.70	-42.70	-27.74	179.9	-148.7	-148.7	-179.4
304.0	-22.86	-43.39	-43.39	-27.84	178.9	-149.0	-149.0	-179.5
306.0	-23.02	-44.11	-44.11	-27.94	177.9	-149.1	-149.1	-179.6
308.0	-23.18	-44.86	-44.86	-28.03	177.0	-149.1	-149.1	-179.7
310.0	-23.35	-45.64	-45.64	-28.13	176.2	-148.9	-148.9	-179.7
312.0	-23.51	-46.47	-46.47	-28.22	175.4	-148.4	-148.4	-179.8
314.0	-23.68	-47.34	-47.34	-28.31	174.7	-147.7	-147.7	-179.8

316.0	-23.84	-48.26	-48.26	-28.39	174.0	-146.6	-146.6	-179.9
318.0	-24.00	-49.24	-49.24	-28.48	173.3	-145.0	-145.0	-179.9
320.0	-24.16	-50.27	-50.27	-28.56	172.7	-142.9	-142.9	-179.9
322.0	-24.32	-51.37	-51.37	-28.65	172.2	-140.1	-140.1	-179.9
324.0	-24.48	-52.53	-52.53	-28.73	171.7	-136.4	-136.4	-179.9
326.0	-24.64	-53.74	-53.74	-28.81	171.2	-131.5	-131.5	-179.9
328.0	-24.79	-54.96	-54.96	-28.89	170.8	-124.9	-124.9	-179.9
330.0	-24.95	-56.13	-56.13	-28.97	170.3	-116.3	-116.3	-179.9
332.0	-25.10	-57.12	-57.12	-29.05	170.0	-105.5	-105.5	-179.9
334.0	-25.25	-57.75	-57.75	-29.13	169.6	-92.7	-92.7	-179.9
336.0	-25.40	-57.88	-57.88	-29.20	169.3	-79.2	-79.2	-179.9
338.0	-25.55	-57.51	-57.51	-29.28	169.0	-66.4	-66.4	-179.8
340.0	-25.70	-56.80	-56.80	-29.36	168.7	-55.6	-55.6	-179.8
342.0	-25.84	-55.90	-55.90	-29.43	168.4	-46.9	-46.9	-179.8
344.0	-25.99	-54.96	-54.96	-29.51	168.1	-40.2	-40.2	-179.7
346.0	-26.13	-54.04	-54.04	-29.58	167.9	-35.0	-35.0	-179.7
348.0	-26.28	-53.16	-53.16	-29.66	167.6	-31.0	-31.0	-179.6
350.0	-26.42	-52.35	-52.35	-29.73	167.4	-27.8	-27.8	-179.5

CPU time = 00:00:57

Appendix C

Unloaded Input Impedance and Gain Output

Solution for input impedance and gain of a microstrip patch
centered at the origin.

X directed length of the patch = 50.000 cm

Y directed width of the patch = 40.000 cm

Thickness of the substrate = 2.0000 cm

Dielectric constant = 2.50 Loss tangent = 0.0010

Location of feed port: X = 23.000 cm, Y = 18.000 cm
with wire radius = 0.0000 cm

Location of load port: X = -18.000 cm, Y = -13.000 cm
with wire radius = 0.0000 cm

Angle of radiated field: Theta = 60.00 deg., Phi = 45.00 deg.

Load port is open circuited.

Mode information:

Number of modes = 4

Modes:

1 0 X polarized

1 1 X polarized

1 0 Y polarized

1 1 Y polarized

FMHZ	INPUT IMPEDANCE		GAIN IN DB	
	Re(Zin)	Im(Zin)	THETA	PHI
150.0	0.22	19.43	1.52	-11.24
152.0	0.25	20.17	1.63	-10.77

154.0	0.28	20.98	1.72	-10.31
156.0	0.32	21.86	1.79	-9.85
158.0	0.37	22.83	1.85	-9.40
160.0	0.43	23.91	1.89	-8.96
162.0	0.50	25.12	1.92	-8.52
164.0	0.59	26.50	1.93	-8.08
166.0	0.72	28.07	1.93	-7.64
168.0	0.88	29.90	1.91	-7.20
170.0	1.10	32.07	1.87	-6.76
172.0	1.40	34.70	1.82	-6.31
174.0	1.86	37.96	1.75	-5.85
176.0	2.55	42.16	1.65	-5.40
178.0	3.70	47.82	1.53	-4.93
180.0	5.80	55.92	1.38	-4.46
182.0	10.22	68.53	1.19	-3.99
184.0	21.90	90.67	0.96	-3.52
186.0	67.93	132.71	0.67	-3.04
188.0	252.85	44.31	0.31	-2.57
190.0	83.89	-98.05	-0.13	-2.10
192.0	27.28	-55.98	-0.69	-1.65
194.0	13.26	-32.55	-1.40	-1.22
196.0	8.03	-19.08	-2.30	-0.83
198.0	5.58	-10.26	-3.46	-0.47
200.0	4.29	-3.87	-4.99	-0.18
202.0	3.56	1.16	-7.05	0.05
204.0	3.17	5.38	-10.01	0.20
206.0	3.00	9.14	-14.78	0.26
208.0	3.00	12.67	-26.58	0.24
210.0	3.18	16.16	-21.25	0.14
212.0	3.55	19.76	-13.37	-0.04
214.0	4.17	23.67	-9.52	-0.28
216.0	5.17	28.11	-7.05	-0.57
218.0	6.79	33.40	-5.29	-0.91
220.0	9.53	40.01	-3.97	-1.27
222.0	14.51	48.67	-2.95	-1.65
224.0	24.53	60.31	-2.14	-2.05
226.0	47.42	74.18	-1.48	-2.46
228.0	99.53	71.33	-0.93	-2.86
230.0	134.97	-6.73	-0.48	-3.27

232.0	78.66	-55.81	-0.09	-3.67
234.0	39.42	-48.97	0.24	-4.07
236.0	22.37	-36.53	0.52	-4.47
238.0	14.28	-26.70	0.77	-4.86
240.0	9.95	-19.32	0.99	-5.25
242.0	7.38	-13.60	1.18	-5.65
244.0	5.75	-9.01	1.35	-6.04
246.0	4.66	-5.16	1.51	-6.44
248.0	3.89	-1.83	1.64	-6.85
250.0	3.34	1.15	1.77	-7.26
252.0	2.94	3.88	1.88	-7.69
254.0	2.64	6.45	1.98	-8.14
256.0	2.43	8.93	2.07	-8.61
258.0	2.28	11.38	2.14	-9.09
260.0	2.18	13.83	2.21	-9.60
262.0	2.14	16.34	2.28	-10.12
264.0	2.14	18.95	2.33	-10.65
266.0	2.19	21.72	2.39	-11.19
268.0	2.29	24.70	2.43	-11.72
270.0	2.46	27.97	2.48	-12.23
272.0	2.71	31.61	2.53	-12.69
274.0	3.06	35.74	2.57	-13.10
276.0	3.56	40.51	2.62	-13.43
278.0	4.26	46.15	2.68	-13.67
280.0	5.27	52.97	2.73	-13.84
282.0	6.77	61.45	2.79	-13.93
284.0	9.07	72.37	2.85	-13.95
286.0	12.85	87.00	2.92	-13.92
288.0	19.55	107.69	2.99	-13.86
290.0	33.00	139.03	3.06	-13.77
292.0	65.41	190.62	3.14	-13.66
294.0	169.42	276.23	3.21	-13.54
296.0	539.64	202.82	3.29	-13.42
298.0	357.74	-300.22	3.37	-13.30
300.0	119.56	-240.10	3.45	-13.19
302.0	54.95	-171.84	3.53	-13.07
304.0	31.29	-131.26	3.62	-12.96
306.0	20.27	-105.63	3.70	-12.85
308.0	14.27	-88.17	3.78	-12.75

310.0	10.65	-75.57	3.87	-12.65
312.0	8.29	-66.05	3.96	-12.55
314.0	6.66	-58.59	4.04	-12.46
316.0	5.49	-52.60	4.13	-12.37
318.0	4.61	-47.66	4.22	-12.28
320.0	3.94	-43.52	4.31	-12.19
322.0	3.41	-40.00	4.40	-12.10
324.0	2.98	-36.96	4.49	-12.01
326.0	2.64	-34.30	4.58	-11.93
328.0	2.35	-31.96	4.68	-11.84
330.0	2.10	-29.88	4.77	-11.75
332.0	1.89	-28.01	4.87	-11.66
334.0	1.72	-26.33	4.97	-11.57
336.0	1.56	-24.80	5.07	-11.48
338.0	1.42	-23.40	5.17	-11.39
340.0	1.30	-22.12	5.28	-11.29
342.0	1.20	-20.94	5.39	-11.19
344.0	1.10	-19.85	5.49	-11.09
346.0	1.02	-18.84	5.61	-10.98
348.0	0.94	-17.90	5.72	-10.88
350.0	0.87	-17.01	5.84	-10.76

CPU time = 00:00:44

Appendix D

Loaded Input Impedance and Gain Output

Solution for input impedance and gain of a microstrip patch centered at the origin.

X directed length of the patch = 50.000 cm

Y directed width of the patch = 40.000 cm

Thickness of the substrate = 2.0000 cm

Dielectric constant = 2.50 Loss tangent = 0.0010

Location of feed port: X = 23.000 cm, Y = 18.000 cm
with wire radius = 0.0000 cm

Location of load port: X = -18.000 cm, Y = -13.000 cm
with wire radius = 0.0000 cm

Angle of radiated field: Theta = 60.00deg., Phi = 45.00deg.

Load port is terminated by 25.0 +j 0.0 ohms.

Mode information:

Number of modes = 4

Modes:

1 0 X polarized

1 1 X polarized

1 0 Y polarized

1 1 Y polarized

FMHZ	INPUT IMPEDANCE	GAIN IN DB		
	Re(Zin)	Im(Zin)	THETA	PHI
150.0	1.89	15.81	-11.89	-24.22
152.0	2.00	16.27	-11.66	-23.61

154.0	2.12	16.76	-11.44	-23.01
156.0	2.26	17.27	-11.24	-22.40
158.0	2.42	17.80	-11.05	-21.80
160.0	2.60	18.36	-10.87	-21.20
162.0	2.80	18.96	-10.70	-20.60
164.0	3.03	19.58	-10.55	-20.00
166.0	3.30	20.24	-10.41	-19.39
168.0	3.62	20.94	-10.29	-18.79
170.0	3.98	21.69	-10.18	-18.18
172.0	4.41	22.48	-10.09	-17.56
174.0	4.92	23.31	-10.02	-16.93
176.0	5.52	24.20	-9.96	-16.30
178.0	6.26	25.13	-9.92	-15.65
180.0	7.15	26.11	-9.91	-14.99
182.0	8.25	27.12	-9.92	-14.30
184.0	9.63	28.14	-9.97	-13.60
186.0	11.36	29.10	-10.04	-12.87
188.0	13.56	29.89	-10.16	-12.11
190.0	16.33	30.29	-10.34	-11.32
192.0	19.73	29.91	-10.58	-10.49
194.0	23.56	28.14	-10.91	-9.61
196.0	26.98	24.27	-11.36	-8.67
198.0	28.31	18.32	-12.00	-7.67
200.0	25.97	12.06	-12.93	-6.60
202.0	20.56	8.24	-14.35	-5.46
204.0	14.56	7.88	-16.71	-4.26
206.0	9.76	9.97	-21.21	-3.03
208.0	6.56	13.20	-26.65	-1.87
210.0	4.70	16.79	-17.86	-0.94
212.0	3.81	20.39	-12.33	-0.49
214.0	3.64	23.91	-9.27	-0.66
216.0	4.03	27.34	-7.65	-1.39
218.0	4.91	30.70	-6.89	-2.46
220.0	6.25	34.01	-6.58	-3.65
222.0	8.07	37.29	-6.50	-4.85
224.0	10.42	40.51	-6.55	-5.99
226.0	13.36	43.62	-6.66	-7.06
228.0	16.96	46.54	-6.80	-8.07
230.0	21.29	49.13	-6.97	-9.00

232.0	26.36	51.19	-7.15	-9.88
234.0	32.15	52.48	-7.33	-10.71
236.0	38.51	52.74	-7.53	-11.49
238.0	45.20	51.73	-7.73	-12.23
240.0	51.83	49.30	-7.94	-12.94
242.0	57.98	45.46	-8.15	-13.63
244.0	63.20	40.42	-8.38	-14.29
246.0	67.20	34.52	-8.61	-14.93
248.0	69.85	28.20	-8.85	-15.56
250.0	71.18	21.88	-9.09	-16.17
252.0	71.39	15.89	-9.35	-16.77
254.0	70.73	10.43	-9.61	-17.36
256.0	69.44	5.60	-9.89	-17.94
258.0	67.75	1.40	-10.17	-18.52
260.0	65.85	-2.22	-10.46	-19.10
262.0	63.85	-5.33	-10.76	-19.67
264.0	61.83	-8.02	-11.06	-20.24
266.0	59.86	-10.37	-11.37	-20.81
268.0	57.94	-12.45	-11.68	-21.37
270.0	56.09	-14.33	-11.99	-21.94
272.0	54.30	-16.04	-12.29	-22.50
274.0	52.55	-17.63	-12.59	-23.06
276.0	50.83	-19.12	-12.87	-23.62
278.0	49.12	-20.54	-13.13	-24.16
280.0	47.41	-21.88	-13.36	-24.69
282.0	45.66	-23.14	-13.56	-25.21
284.0	43.88	-24.33	-13.71	-25.69
286.0	42.05	-25.43	-13.80	-26.15
288.0	40.17	-26.42	-13.84	-26.56
290.0	38.25	-27.31	-13.82	-26.91
292.0	36.28	-28.06	-13.73	-27.20
294.0	34.28	-28.67	-13.58	-27.42
296.0	32.27	-29.14	-13.38	-27.56
298.0	30.27	-29.45	-13.13	-27.61
300.0	28.28	-29.61	-12.83	-27.59
302.0	26.34	-29.62	-12.50	-27.50
304.0	24.46	-29.50	-12.14	-27.34
306.0	22.65	-29.25	-11.76	-27.13
308.0	20.92	-28.89	-11.37	-26.87

310.0	19.29	-28.42	-10.97	-26.58
312.0	17.75	-27.88	-10.56	-26.26
314.0	16.32	-27.26	-10.16	-25.93
316.0	14.99	-26.59	-9.76	-25.58
318.0	13.76	-25.88	-9.36	-25.23
320.0	12.62	-25.14	-8.97	-24.88
322.0	11.57	-24.38	-8.59	-24.53
324.0	10.62	-23.61	-8.22	-24.19
326.0	9.74	-22.83	-7.85	-23.85
328.0	8.94	-22.06	-7.49	-23.51
330.0	8.21	-21.30	-7.14	-23.18
332.0	7.54	-20.54	-6.80	-22.86
334.0	6.93	-19.80	-6.47	-22.54
336.0	6.37	-19.07	-6.15	-22.24
338.0	5.87	-18.36	-5.83	-21.94
340.0	5.40	-17.68	-5.53	-21.64
342.0	4.98	-17.01	-5.22	-21.36
344.0	4.59	-16.36	-4.93	-21.08
346.0	4.24	-15.73	-4.64	-20.80
348.0	3.91	-15.12	-4.36	-20.53
350.0	3.62	-14.53	-4.09	-20.27

CPU time = 00:01:42

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